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PROCEEDINGS

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DISCUSSION
OF PROCEEDINGS - SEPARATES

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SURVEYING AND MAPPING
DIVISION

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GEORGE F. SOWERS,[38] A.M. ASCE.—Highway planners and designers, as well as soils engineers, will find the information which Mr. Woods has presented to be of great value. It is the writer's opinion, however, that a mere description of the methods of exploration that are in use is not sufficient. Most engineers are familiar with the well-established procedures for making soil surveys, however, techniques such as the use of pedological data and geophysical methods are not so clearly understood. Unfortunately, the enthusiasm with which these methods have been advocated and adopted has not always been accompanied by a thorough consideration of what information these methods can and cannot supply

In making soil surveys the engineer has depended on direct methods, such as borings and test pits. Newer fields of science have made available both ready-made data on soil conditions and indirect techniques of making soil surveys. These approaches have the important advantage of providing extensive data at a lower cost than do the older methods, but they do have inherent shortcomings which should be clearly understood by the engineers who use them.

Geological and Pedological Data.—The geological and pedological surveys, mentioned by Mr. Woods, classify soils primarily on the basis of genealogy (including the age of the deposit), its method of formation, and the type of soil (usually based on texture or mineralogy) of which it is composed. This information is helpful, but it does not supply the answers to specific engineering problems.

These questions may be answered in one of two ways. In some states the different geologic and pedologic groups are correlated with soil performance. The design problems affected by the soil are then solved by empirical relationships. Unfortunately, the basic geologic and pedologic classifications ignore many of the pertinent soil properties. Consequently, the correlations between performance and soil group are often rather crude and sometimes little better than guesswork. If, in the design, the average correlation of values is used, occasional failures must be expected; if the correlation is conservative, there will be many cases of overdesign. The writer believes that such an empirical approach is fundamentally unsound. It encourages shortsighted designers to follow a set rule without the need for determining the best design for each set of soil conditions. Furthermore, this approach tends to stifle productive research for better methods of correcting difficult situations, since it concentrates attention on methods of classifying soils rather than on methods of evaluating the physical properties of a soil.

The second approach described by Mr. Woods is to use the pedological and geological data to define areas in which the soil conditions are likely to be homogeneous. Representative samples from each area are tested to deter-

[38] Associate Prof. of Civ. Eng., Georgia Inst. of Technology, Atlanta, Ga.; Cons. Engr., Law-Barrow-Agee Labs., Atlanta, Ga.

mine the soil properties and the range of these properties. The design can then be based on actual test results rather than on some empirical correlation. If the range of the properties within any one area is so great that a safe, economical design cannot be had, all that is necessary is to increase the amount of sampling and testing so as to secure more extensive data. The use of this approach stimulates research into the causes and cures of highway difficulties, since the engineers deal with the physical properties of the soil in their everyday problems.

Geophysical Methods.—As Mr. Woods states, the geophysical methods of exploration have been used in highway work to some extent since 1930. In more recent years, the development of more compact equipment by organizations engaged in mineral exploration has resulted in increased interest and more extensive use of geophysical exploration in all civil engineering site investigations. The author does not point out, however, that geophysical exploration has limitations which can discredit its use if those limitations are not clearly understood.

The geophysical methods do not directly determine the locations of soil and rock strata. Instead, they measure changes in effects of a force such as an electric current or a shock wave on the earth. These changes, in many cases, can be interpreted so as to obtain an estimate of the soil and rock conditions.

Seismic Method as Applied to Civil Engineering.—The seismic method utilizes the different velocities of a shock wave in soils and rocks to determine the thicknesses of the strata. The ideal situation for the application of seismic exploration consists of horizontal, well-defined strata in which the velocity of sound becomes greater in each deeper stratum. When underground conditions resemble the ideal, the seismic method yields accurate, dependable information, but if the underground conditions differ from the ideal, the results may be far from reliable.

One application in which the method has proved useful is in the determination of the thickness of unconsolidated mantle overlying bedrock. It has been particularly useful in the preliminary studies for bridge and dam foundations where sound rock may be covered by several hundred feet of boulder-filled materials. It may also be used when the ground surface is covered with water. In some cases it has been possible to use this method for determining the thickness of different strata of unconsolidated materials. Unfortunately, however, the velocities in unlike soil strata may be so nearly alike that the method is of little value for this purpose.

In many cases it has been possible to identify consolidated and unconsolidated materials from the velocities of wave travel in them. It has been possible in some areas to correlate the engineering properties, such as strength, with the velocities so that the seismic data can be used to predict the structural capabilities of the materials. However, such relations apply only to the materials of a restricted group and should not be used indiscriminately.

When the rock surface is very irregular or deeply weathered, the seismic refraction method is of doubtful value. So many different interpretations of the data are possible that the results are of little use to either the planner or

the designer. When the velocities within the strata decrease with increasing depth, or when the velocities vary erratically, the results of the method may be of little value. The water table often confuses seismic data so that rational interpretation is impossible.

Electrical Resistivity Methods.—The electrical resistivity methods are based on the fact that different soils and rocks offer different resistances to the passage of an electric current. Two methods are commonly used. In the first, the soil resistivity is measured at one location between two electrodes whose spacing is increased by increments. A graph showing resistivity as a function of electrode spacing is prepared and the curve is analyzed to determine the depth of strata having different resistances.

The first method is well-suited to the determination of the depth and thickness of soil strata having great differences in resistance. Since electrical resistance depends largely on the degrees of ionization, materials that differ greatly in water content, porosity, and chemical composition are likely to have different resistances. Moist clays and silts ordinarily have low resistances whereas sands, gravels, dry soils, and rocks have high resistances.

This method has proved particularly useful for locating sound rock when the rock lies at depths of less than 75 ft. This makes it adaptable to preliminary surveys for highway location where the possibility of rock excavation is an important factor in the determination of the final design. The method has also been successful in locating the water table in sands and gravels and other soils which have high resistances when dry. In areas where the soil profile consists of alternate strata of dry sands and gravels and moist clays, it has been possible to identify the depth and thickness of each stratum, and in a few instances it has been possible to identify the materials by their resistances. Such identifications must be confirmed by borings before they can be used for engineering purposes.

The second method, often termed the "constant-depth traverse," or "resistivity traverse," uses a constant electrode spacing and requires measurements at many different locations over the project site. From these data "contour" maps of resistivity are prepared which show areas of high and low values. Since dry sands and gravels have high resistivities, this method is particularly useful for locating such deposits and for showing the location at which the deposit is likely to be the thickest. It also could be used in preliminary studies of marsh areas to locate sand bars and similar soils of relatively high bearing capacity. This method might also be used to trace the beds of buried glacial streams for ground-water supplies. In areas where the rock is deep and foundations must extend down to it, the method can define the areas where rock lies closest to the ground surface.

Value of Geophysical Methods.—The geophysical methods of exploration are indirect means of identifying marked differences in the electrical resistance or wave velocities of the underground materials. The methods are useful only if these differences can be accurately interpreted in terms of engineering data, and if the data can be secured as easily and as economically as similar data obtained by other methods of exploration.

The depth and thickness of the strata can be estimated with an accuracy of about 1 ft or 2 ft, if the underground conditions approach the ideal of horizontal well-defined strata. Unfortunately, there have been instances in which the data indicate that the conditions are ideal and the measurements of depth and thickness have been 50% in error. When the underground conditions are far from ideal, such as when the upper surface of bedrock is very irregular or badly weathered, the results may be inaccurate and misleading. On one project, in North Carolina during 1951, the seismic refraction records indicated that sound rock was at a uniform depth of 30 ft and was overlain by unconsolidated materials. When the site was excavated, however, rock was found at a depth of 15 ft, but was somewhat irregular.

TABLE 1.—Relative Merits of Geophysical Methods and Comparable Boring Methods

Method	Equipment cost (in dollars)	Typical weight (in lb)	Minimum crew	Cost per ft of depth[a] (in dollars)	Advantages	Disadvantages and limitations
Hand auger.....	10	10	1	0.50–1.00	Soil samples	Limited by gravel and ground-water table, 30-ft maximum depth.
Two-man powered auger	500	80	2	0.25–0.50	Soil samples	Limited to from 6-ft to 8-ft depth. Cannot bore coarse gravel.
Jeep-mounted powered auger	3,500	3,000	1	0.30–1.00	Soil samples	Limited by boulders and ground water.
Wash boring....	500	200	2	0.30–1.00	Washed "samples"	Cannot bore gravel.
Seismic.....	4,000	150	3 to 4	0.25–0.50	Not hampered by boulders	Boring confirmation necessary. Unreliable if rock surface is irregular. Estimated soil character only. Requires explosives.
Resistivity.....	500	25	2 to 3	0.25–0.50	Not hampered by boulders	Boring confirmation necessary. Estimated soil character only. Affected by strong electric current.

[a] Commercial cost including overhead and reporting of data.

A resistivity survey of a building site in Georgia during 1952 was used to establish the depth to rock. Subsequent borings indicated that the minimum error of the actual depth to rock was 40% and the average error was 160%.

In some cases the geophysical methods suffer from outside limitations. For example, the seismic method often cannot be used in cities because of restrictions on explosives. In 1952 the electrical resistivity method was used to determine the depth of an old rubbish dump in Altanta, Ga. The measurements were completely obscured by electrical currents generated by the action of acid-forming cinders and metal in the fill.

The geophysical data only indicate the engineering characteristics of the materials. In any one area it is sometimes possible to establish an empirical correlation between resistivity of wave velocity and properties such as strength. However, such relationships are crude at best and furnish only limited infor-

mation for the planning stages of a project. Since the relationships are empirical, it is dangerous to apply the experience gained in one region to materials from another region with different geologic characteristics.

The information obtained by geophysical exploration is in many ways comparable to that obtained by wash boring, hand auger boring, or power auger boring. The decision of whether to use the geophysical methods or the direct methods depends largely on convenience and cost. In general, the geophysical equipment is expensive and relatively fragile and requires trained personnel and experienced supervision in order to obtain even passable results. On the other hand, a well-trained crew is able to secure considerable data in a short time. The comparable simple boring methods (except power augers) require relatively inexpensive, easily portable equipment and do not necessarily require trained personnel to obtain good results. In some situations, such as with irregular rock, the geophysical methods may prove useless, whereas in other situations, such as with a boulder-filled deposit, the simple boring methods are useless.

Table 1 shows some of the relative merits of geophysical methods compared with the more common direct method.

K. B. Woods,[39] M. ASCE.—Mr. Sowers, in his discussion of the original paper, has supplied some additional and important data in the field of explorations, particularly with respect to geophysical methods. The research of C. R. Lennertz, J. M. ASCE, in the field of electrical resistivity exploration, supports Mr. Sowers' observation as to the dependability and need of collaborating information. Experiments to date (1953) indicate the need of some type of control data when exploring alluvial deposits and locating bedrock that is covered with glacial and alluvial sediments. However, many highway departments are finding the electrical resistivity technique an economic and useful tool to supplement many of their exploratory programs.[40]

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[39] Associate Director, Joint Highway Research Project, and Prof. of Highway Eng., Purdue Univ., Lafayette, Ind.

[40] "Soil Investigation Employing a New Method of Layer-Value Determination for Earth Resistivity Interpretation," by H. E. Barnes, *Bulletin No. 65*, Highway Research Board, National Research Council, 1952, pp. 26–36.

DISCUSSION OF A PROPOSED METHOD FOR THE TRANSIT LINING OF HIGH-SPEED TRACK PROCEEDINGS-SEPARATE NO. 271

HARRY RUBEY[1], M. ASCE. — The paper under discussion is important not only as an ingenious application of surveying and a well-developed study for improving track alignment, but also as promoting use of the increasingly necessary transit lining of railway curves that will result in better alignment standards. The preference for this method by the New York Central System, Lines West, is to be commended.

With increasing speeds and track standards essential for meeting the competition of other forms of transportation, railways must improve curve alignment. Many maintenance engineers will prefer transit lining for a considerable part of their programs. It is therefore urgent that this subject be thoroughly discussed at this time and especially necessary that alternative methods for transit lining be made a part of the discussion.

String lining became popular during the depression and during World War II, partly on its merits and partly because of the scarcity of engineering personnel. More recently, engineering personnel is being channeled into management and the resultant shortage of engineers for transit lining tends further to popularize string lining. Of undoubted value for smoothing curves, string lining frequently has been used where transit lining would be better. As the author implies, important track should be lined correctively toward a perfect transit curve rather than in the makeshift manner that is encouraged by string lining. Actually, string lining may be used under certain conditions and transit lining under others.

The author's paper presents a valuable analysis and helpful suggestions for aligning the tangents, for improving the clearance on multiple track, for gradual corrective lining of the curves toward an ultimately optimum alignment, and for monumenting the control points. Fortunately his analysis, or applications of his analysis, may be used with other methods of lining the curves.

The ingenious coordinate method used by the author on the curve appears to be practical except that for many railways it requires too much of a specialized surveying skill, too much time, too much travel, too much office work, and too much office selection of the optimum alignment. The factors influencing the alignment decision can be evaluated equally well or better while in the field. This method would appear suitable where heavy traffic prevails, where a highly organized division office exists, where engineering personnel is abundant and relatively stable, and where engineering standards are high.

The reader is referred to a simpler alternative method of transit realignment for the curve.[2] This method was developed to permit complete staking

1. Chmn. of Civ. Eng. Dept. Univ. of Missouri, Columbia, Mo.
2. "A New Transit Method for Realigning Railway Curves and Spirals" by Harry Rubey, Bulletin No. 34, Engineering Experiment Station, University of Missouri, Columbia, Missouri, 1946, 40 pp. Copies gratis.

of a not-too-difficult curve in one day of field work. Tables and diagrams are included which speed the work in the field; without them the time lost by the field party, while computations are being made, would be prohibitive. It is thought to be a simple, easy, quick, and cheap method with the added advantage of selecting the optimum curve in the field where all influencing factors may be weighed to advantage.

Unless an economical method for transit lining receives wide recognition, string lining will continue in use even where transit lining is preferable.

The author has presented a method of transit lining that he proposed be studied and possibly revised. With this proposal the writer (discusser) agrees, but further recommends that all other methods of transit lining be studied at the same time as alternatives.

DISCUSSION OF SURVEYS AND MAPS — VITAL TO THE PROBLEMS OF MASS TRANSPORTATION
PROCEEDINGS-SEPARATE NO. 305

MILTON O. SCHMIDT[1], A.M. ASCE.—The author has intimated that no other industry in the United States has contributed so much to the development of this country as that of transportation. Extreme mobility characterizes our way of life. Man is no longer self-sufficient. The free and expeditious exchange of commodities and the rapid, economical transport of human beings are indispensable requisites for 20th century living. Today's farmers, industrial workers, housewives, and even teen-agers, too, consider fast and convenient transportation a vital necessity.

Although much of America's transportation plant, particularly its railroads and highways, literally sprang into being, the subsequent expansion of the various systems, their modernization, and the development of airways, waterways, pipelines, and other forms of transport requires adequate engineering data of good quality. Such technical information is largely provided by engineering surveys of all types including cadastral, soil, and traffic surveys as well as topographic and various other kinds of maps. Surveys and maps play a vital role, therefore, in the expansion, modernization, and development of American's transportation systems. Those route studies that are based on surveys and maps, when viewed in the light of sound engineering principles, lead us to several conclusions; viz., where to build, when to build, and whether to build at all. Sometimes, also, they recommend, as in the case of railways, the abandonment of existing facilities.

If we forget for a moment the multiplicity of details that envelop the typical transportation study and keep in mind the foregoing basic objectives, it is to be emphasized that once the problem is stated, the surveyor-engineer and the mapper can be of inestimable value in gathering the data upon which the best solution can be based. Proceeding with a transportation design without good quality data is just as poor engineering as dimensioning a truss or a beam without adequate knowledge of the load it must sustain or of the properties of the metal from which it is fabricated. However, the poorly-designed bridge may sway uncomfortably, deflect excessively, and in the worst cases, fail; but the consequences of a poor highway or pipeline location may not be evident for many years although the economic consequences may be just as severe. This is particularly true in railroad engineering where high operational costs may finally dispute the wisdom of a particular location which seemed to be the best one possible.

A principal theme of this paper is that surveying and mapping for America's transportation plant have not kept pace with the vast advances in design that have taken place. Although the art and science of surveying and mapping have been greatly developed in recent years, the full significance of the immediate and potential value of survey data and maps is as yet not readily appreciated

Note. — Published in October, 1953, as Proceedings-Separate No. 305 by Benjamin Everett Beavin, Sr., M. ASCE.

1. Prof. of Civ. Eng., Univ. of Illinois, Urbana, Ill.

by many civil engineers. On the contrary, there has remained a persistent reluctance to allocate to surveys and mapping an adequate portion of the total costs of a project. However, a dollar saved on a poorly-executed or inadequate survey is not a prudent action. Higher quality surveys are needed in the expansion and development of today's transportation plant.

Contemporary engineering projects are much larger and consequently, much more costly than those of only 10 years ago. Land acquisition is expensive and construction investments involve huge sums of money. One can no longer prosecute even the most preliminary of surveys in a rough manner reminiscent of the old reconnaissance surveys because the economic implications are much more important. Years ago such surveys might have been quite satisfactory especially when interpreted by one of broad judgment and penetrating divination and when these were buttressed with a profound trust in the Lord.

In the field of highway engineering alone it has been recently estimated that the total annual mileage of surveys and resurveys may reach the amazing total of 26,000.[2] This figure undoubtedly includes the many miles of turnpikes that have been built and are currently under construction. Future statistics will continue to contain sizeable amounts for new turnpikes. When to this total one adds the surveys required for the extensive railroad relocations that have been executed in the Tennessee Valley and as part of other drainage basin improvement programs as well as of primary line and grade reduction projects, the figures become very impressive. It is necessary to recall also, the extensive mileage of new gas and oil lines that are being built each year and the surveys needed for such notable structures as the Chesapeake Bay Bridge with which the author has been connected, the Mackinac Straits Bridge, and important tunnel and other subsurface transportation engineering works. One then begins to obtain an adequate concept of the place of survey data and maps in this area of civil engineering practice. Nevertheless, important as such data have been, they have played a relatively mute role and there are to be found in our consulting engineering offices, and in the highway, railroad, and municipal engineering organizations few advocates for an adequate and clearer perception and understanding of the total surveying problem particularly in the light of the ultimate required accuracies. The social status of surveying and mapping in the profession of civil engineering and, also, in civil engineering education has been depressingly low. There are department heads at some civil engineering schools who deplore the time still given to instruction in this field. Special interests frequently engage their attention and they can see nothing in surveying. However, catholicity of interests and broadness of outlook should characterize the administration of any curriculum in engineering.

It must be evident, then, that thousands of miles of route surveys are executed every year. They range from those needed for minor revisions of secondary roads to those preceding the construction of transportation facilities of great magnitude. Still too frequently, mediocrity of planning and execution characterize them. Piece-meal, and short-sighted surveys, inadequately monumented and poorly referenced stations, and the use of a multiplicity of horizontal and vertical datums tells the story.

On the educational scene our surveying instructions must be more than a course in instrumentation and field and office techniques. It must present the basic issues of an engineering survey—the policies, the specifications,

2. "Photogrammetry as Applied to Highway Engineering" by Jon S. Beazley, Photogrammetric Engineering, vol. XVII, No. 1, March 1951.

and the procedures affecting them, and provide an insight as to the usefulness of survey and map data to the practicing engineer. The problems of transportation surveying are no longer solved by the Wellingtons or those like John F. Stevens, one-time President of this society, who discovered Marias Pass in the Rockies for the Great Northern Railroad. The major decisions are reached by today's engineering executives who depend upon but do not, unfortunately, always insist upon high quality survey data and superior maps. The ordinary survey will do after a fashion, but the superior one, well-planned, skillfully executed, and its results expertly portrayed will provide a sounder base for preliminary studies, final design and operation, and exemplify the economic goal of good professional engineering practice. Concerning maps, there can be no question of their value. But engineers have been slow to look about themselves and exploit to the fullest possible extent available cartographic information.

From a military standpoint mobility is the essence of strategy. The history of General Patton's movements in Europe during World War II document this dependence of the military upon maps. For national security reasons we need to inventory our transportation plant on a common horizontal and vertical reference framework—to keep that inventory up to date—and to plan for plant expansion intelligently and economically. Such action will be aided through the widest possible utilization of data from well-executed surveys and the study of maps.

In summary it is emphasized that surveying and mapping have always been the means to an end. The execution of surveys and the preparation of maps are only the prelude to the design and construction of civil engineering works. In problems of transportation plant, surveying and mapping have always been of great assistance. In this role they will continue to serve and the wisdom of the engineer will be mirrored by the emphasis he places upon the need of and the support he secures for obtaining good surveys and maps. Our profession of civil engineering should indeed look ahead and anticipate in its surveying and mapping programs the needs, present and future, of America's transportation systems. The engineering schools wish to perform ably in this area of civil engineering education. They invite criticism and ask for encouragement and good advice from the practicing engineers.

PROCEEDINGS-SEPARATES

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The technical papers published in the current calendar year are presented below. Technical division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering."

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[a]Discussions grouped by Divisions.

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